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turity, should assist materially in revealing the cause of spot formation. Their frequency of occurrence is probably much greater than these first results suggest, as our winter observations have been seriously limited by exceptionally cloudy weather, poor seeing, and low solar activity.

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[1] Hale, On the Probable existence of Magnetic Fields in Sun-spots. *Mount Wilson Contr.*, No. 30; *Astroph. J., Chicago,* **28,** 1908 (315–343).

[2] Hale, Ellerman, Nicholson, and Joy. The Magnetic Polarity of Sun-spots. *Mount Wilson Contr.*, No. 165; *Astroph. J., Chicago,* **49,** 1919 (153–178).

COMPARISON OF THEORY WITH OBSERVATION FOR THE MINOR PLANETS 10 HYGIEA AND 175 ANDROMACHE WITH RESPECT TO PERTURBATIONS BY JUPITER

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The perturbations of the minor planets 10 Hygiea and 175 Andromache, developed by Dr. Estelle A. Glancy and Dr. Sophia H. Levy on the basis of the revision of von Zeipel's formulae and tables of minor planets which have a mean motion approximately twice that of Jupiter, (Hecuba Group), have lately been severely tested by comparison of recent observations with the computed places, for which the numerical work was performed by Dr. H. Thiele. This revision of von Zeipel's theory will soon appear as the third memoir of Volume 14 of the MEMOIRS OF THE ACADEMY. The results of these comparisons are highly encouraging and prove that the revised tables for the Hecuba Group more than meet the practical requirements of a satisfactory representation of the motion of the minor planets belonging to this group. The preliminary conclusions communicated to the Academy at the annual meeting of 1916 in my general report on the perturbations and tables of the minor planets discovered by James C. Watson are thereby fully verified.

Hygiea was discovered on April 12, 1849 by Gasparis. The most accurate of the eariler orbits computed was that by von Zech, which was based on the elements of d'Arrest and the general perturbations, developed by Hansen's method, by Jupiter, Saturn, and Mars, extending over eight oppositions. Since von Zech's death in 1864, his computations have been kept in the Recheninstitut at Berlin and were used by von Zeipel in connection with the application of his approximate perturbations for the Hecuba Group. Von Zech's computations have been continued from year to year at the Berlin Recheninstitut until 1873, up to which time they represented the motion of Hygiea with considerable accuracy. In the Berlin Jahrbuch for 1876 new elements by E. Becker are given. These were later corrected on the basis of oppositions extending from 1868 to 1874 with consideration of the special perturbations by Jupiter and Saturn. These elements have been carried forward with perturbations until 1898 and from that time on until 1920 without change of osculation. For 1920 the elements were improved by the Berlin Recheninstitut by a slight correction of the mean motion so that the last 14 oppositions appear to be represented with an accuracy of $\pm 3'$. In the mean time, however, observations extending from 1915 to 1918 had revealed increasing discrepancies between the observations and computed places. On October 9, 1918, this discrepancy amounted to nearly $2^1/_2{}^\circ$ in right ascension and 1° in declination. These discrepancies have led to new orbits and ephemerides by Blondel, Maitre and Jehkowski, published in the Bulletin of the Observatory at Marseilles and to the latest revision of the elements by the Berlin Recheninstitut. These latter elements will no doubt represent observations at the next few oppositions with a satisfactory degree of accuracy, provided the laborious computation of the special perturbations and the correction of elements from opposition to opposition is kept up. Otherwise large discrepancies are bound to reveal themselves again in the course of a few oppositions. Even then, this piece-meal procedure does not produce a set of elements or a theory of perturbations which will represent the observations in all of the oppositions from 1849 to the present time and for at least an equally long interval in the future.

Aside from the enormous amount of computation of temporary value which is involved, it is necessary to secure frequent observations in order to secure the data for the successive improvement of the elements and perturbations. Thus, during the last ten years, more than 100 accurate photographic and visual observations of Hygiea have been published. These difficulties may now be wholly overcome by the application of von Zeipel's revised Jupiter perturbations of planets for the Hecuba Group and by the application of similar tables to other groups as originally proposed by Bohlin. As stated above, von Zeipel developed the perturbations of Hygiea from his original tables on the basis of von Zech's elements. With these perturbations he represented oppositions from 1849 to 1884. This representation showed a constantly increasing discrepancy which in 1884 had reached $23'$ in right ascension and $9'$ in declination. He therefore corrected the elements by the method of least squares and thereby succeeded in representing the observations satisfactorily until 1914. Discrepancies will hereafter rapidly increase in the opposite direction. The original discrepancies were not due so much to inaccuracy in von Zech's elements as to some inaccuracies in von Zeipel's tables for the Hecuba Group. This is clearly shown by the fact that von Zech's unchanged elements and our revised tables give as satisfactory a representation in the 37 years from 1884 to 1921 as in the preceding 35 years from 1849 to 1884, and that several experiments by Miss Glancy, the last published in 1918 in the Astronomical Journal Number 748, to remove outstanding differences between theory and observation by correcting von Zech's elements have led to invalid results, as in the case of von Zeipel's earlier attempt in the same direction.

Outstanding differences between theory and observation are of the same order of magnitude in the two intervals. In fact in 1917 the discrepancy was less than 1′ in both right ascension and declination, although in a very few of the long series of oppositions positive or negative differences as high as 10′ exist in right ascension. These differences however, are primarily due to perturbations by Saturn which so far have not been taken into consideration. These encouraging results on Hygiea clearly show that on the basis of the revised tables for the Hecuba Group and on the basis of reliable elements determined from a very few oppositions, perturbations may be developed for all planets of this group which will yield a satisfactory theoretical representation of observations for practical purposes. It is safe to say that the abandonment of the piece-meal method of computing special perturbations and correcting elements from opposition to opposition in favor of the group theory will release in the long run a considerable part of the efforts of the astronomers who are engaged in these laborious tasks.

175 Andromache was discovered by Watson on October 1, 1877. A preliminary report on the perturbations of this planet was rendered at the annual meeting of the Academy in 1916. At that time it was pointed out that as shown by the very accurate computations by Berberich at the Recheninstitut of the special perturbations of Jupiter and Saturn, the mean motion had constantly decreased from 617.7 in 1877 to 607.9 in 1910. During the last ten years the osculating mean motion has decreased but slightly. According to Miss Levy's development of the perturbations of Andromache by the revised tables this decrease in the osculating mean motion is due in the main to three long period terms of Jupiter's perturbations having a period of approximately 187, 94, and 62 years, with an amplitude of 23.3° for the perturbation of longest period. By introducing the effect of these long period terms into the mean motion, Dr. Thiele, who has made the necessary computations, and I have approximately reproduced the nearly progressive change in the osculating mean motion as computed by Berberich. By extending this process, we may predict that the minimum value of the osculating mean motion is nearly reached and that within the next few years it will begin to increase. A case of libration is therefore not involved as the mean motion will not pass through the value which is twice that of Jupiter. The maximum value will be reached between the years 2004 and 2016, after which it will again decrease. In fact, none of the cases of planets of the Hecuba Group so far examined

in this manner indicate the existence of a libration. According to all indications, the motion of these planets is therefore entirely stable. The very extensive and accurate computations of Berberich have furnished very reliable sets of osculating elements of Andromache. With Berberich's elements osculating for 1877 and Miss Levy's development of the perturbations on the basis of the revised tables, an observation for the year 1920 has been represented with a remarkable degree of accuracy, so that in this case, also, the process of computing the special perturbations from opposition to opposition and frequent observations may be abandoned for many decades to come.

It is hoped that the results for 10 Hygiea and 175 Andromache here presented will prove a determining factor in the methods hereafter to be applied by astronomers in deriving the approximate perturbations by Jupiter of planets of the Hecuba Group and of other groups with mean motion commensurable to that of Jupiter to which Bohlin's original group theory is applicable with proper modifications and extensions. These studies should form a most fruitful field of research in theoretical astronomy.

A METHOD OF DERIVING THE DISTANCE OF THE A-TYPE STARS

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Our knowledge of the distances of individual stars of the A-type of spectrum is obtained almost wholly from three sources.

1. Trigonometric parallaxes.
2. Dynamical, sometimes called hypothetical, parallaxes of binary stars.
3. Parallaxes derived from group motion.

The third method probably furnishes the most accurate values for all such stars as belong to well-recognized groups. In the case of the Taurus Group, for example, the distances are known with a high degree of precision. The trigonometric parallaxes are, of course, most valuable in the case of large values for which the probable error bears a relatively small ratio to the quantities measured. The dynamical parallaxes derived from binary stars with well-determined orbital motion are of excellent quality, but are affected to some extent by the uncertainty in the value of the mass-factor for the A-type stars which enters directly into the computation.